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NAVY DEPARTMENT
BUREAU OF ENGINEERING
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INSTRUCTIONS FOR THE CARE AND OPERATION OF DISTILLING PLANTS

NAVY DEPARTMENT
BUREAU OF ENGINEERING

WASHINGTON
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1921

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INSTRUCTIONS FOR THE CARE AND OPERATION OF DISTILLING PLANTS.

NAVY DEPARTMENT,
BUREAU OF ENGINEERING, *December 29, 1920.*

These instructions have been compiled for the information and guidance of the naval service. They apply to all types of distilling plants. Commanding officers are requested to address to the Bureau of Engineering requests and recommendations to improve these instructions, including especially any precautions deemed necessary under special conditions and not herein provided for.

R. S. GRIFFIN,
Engineer in Chief, U. S. Navy.

NAVY DEPARTMENT,
Washington, D. C., December 29, 1920.

The "Instructions for the Care and Operation of Distilling Plants" are approved for issue to all officers for their information and guidance. The instructions and recommendations contained therein will be followed on all vessels.

JOSEPHUS DANIELS,
Secretary of the Navy.

INTRODUCTION.

1. These instructions and suggestions are written primarily for officers doing engineering duty. The instructions apply in general to all types of evaporators except where special note is made. Detailed instructions for the operation of the plant on a given ship will be prepared and posted by the engineer officer.

The purpose of a distilling plant on board ship is to produce the required quantity of fresh water with a minimum expenditure of steam. This should be accomplished without unnecessary complications of apparatus and with minimum care and labor on the part of the attendants.

2. Distilling plants on naval vessels are classed as (*a*) high-pressure type and (*b*) low-pressure type.

(*a*) The high-pressure type is designed to operate primarily using steam from auxiliary steam line, and may be piped up to operate in single effect, double effect, or multiple effect (triple or more). Also piping, for operating on steam drawn from the auxiliary exhaust, is generally installed. When auxiliary exhaust is used it is usual on the larger vessels to provide an air pump to produce a vacuum of 20 inches or better on the distillers

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with corresponding low pressure on shell of evaporator, in order to produce a sufficient amount of water. The high-pressure type is in general use with few exceptions.

(*b*) The low-pressure type is designed and rated to operate on steam drawn from the auxiliary exhaust and is always piped up to operate in double or multiple effect. This style—Lillie type—is installed on the *Dixie*, *Salem*, *Tennessee*, and *California*.

The following is a list of distilling plants installed on later battleships and destroyers:

Vessel.	Number installed.	Type.	Heating surface, each.	Rated total capacity.	Remarks.
			Sq. ft.	*Gallons.*	
Delaware and North Dakota.	4	Bureau horizontal	312.00	25,000	Double effect.
Florida and Utah	4	Model bureau horizontal.	312.00	25,000	Do.
Wyoming	4	do	312.90	25,000	Do.
Arkansas	4	do	312.00	25,000	Do.
New York	4	do	194.00	28,000	Do.
Texas	4	Griscom-Russell vertical.	93.60	28,000	Do.
Nevada	4	Griscom-Russell horizontal.	221.40	25,000	Do.
	2	Row & Davis	75.30	12,500	Do.
Oklahoma	4	Schutte-Koerting vertical.	117.78	25,000	Do.
Pennsylvania	4	do	146.47	35,000	Do.
Arizona	4	Bureau horizontal	254.00	25,000	Do.
New Mexico	6	Schutte-Koerting vertical.	113.00	40,200	Do.
Mississippi and Idaho.	4	Griscom-Russell vertical.	120.00	30,000	Do.
Tennessee and California.	6	Lillie horizontal	150.00	37,500	Multiple effect.
Colorado and Washington.	6	Schutte-Koerting vertical.	114.50	37,500	Double effect.
Maryland and West Virginia.	6	Griscom-Russell vertical.	74.48	37,500	Do.
DESTROYERS.					
22, 25, 32, 37	2	Newport News	75.00	3,000	Single effect.
26 to 29, 34, 45	2	Williamson	75.00	3,000	Do.
30, 31, 36	2	Cramp	75.00	3,000	Do.
38 to 40	2	Reilly	61.50	3,000	Do.
41, 42	2	Bath	75.00	3,000	Do.
43, 44, 54	2	do	100.00	3,750	Do.
45, 62	2	Schutte-Koerting	31.79	3,750	Double effect.
46 to 53, 55, 56	2	Reilly	61.50	3,750	Do.
57, 63, 64, 67, 68	2	No. 14, Reilly	86.10	5,400	Do.
58, 59	2	Schutte-Koerting	55.15	5,400	Do.
60, 65, 66, 74	2	Bath	110.00	5,400	Do.
69, 70	2	Schutte-Koerting	50.75	6,000	Do.
71, 72, 73	2	Navy Schutte-Koerting.	32.75	5,400	Do.
75 to 134, 142 to 160	2	No. 16, Reilly	42.56	7,500	Do.
135 to 141, 336 to 341	3	Bureau standard	50.75	9,000	Do.
161 to 335, 342 to 344	2	No. 24, Reilly	63.84	10,500	Do.
345 to 347	2	U tube, Bath type	110.00	10,000	

In the naval service the following ratings for evaporators are standard:

Type.	Gallons per 24 hours per square foot heating surface.	Remarks.
Standard Navy horizontal	25	Single effect.
Schutte-Koerting vertical "U" tube	60	Double effect.
Griscom-Russell vertical "U" tube	60	Do.
Row & Davis vertical coiled tube	60	Do.
Bureau vertical U tube	60	Do.

These are the standards considered by the bureau as the limit for satisfactory all-round operation, but on some vessels where weight is of paramount importance this rating is exceeded for the Griscom-Russell type. It is advisable to operate the evaporators at this standard rate if the quantity needed does not exceed the capacity at this rate.

OPERATION.

3. **General.**—The following notes on operation, intelligently applied, should be helpful to all concerned with the operation of evaporators. Where a positive direction is given the procedure must not be diverged from unless the plant is in such condition that these instructions can not be carried out. Plants piped up to operate in double or multiple effect should be operated in this manner rather than as single-effect evaporators because of the enormous increase in efficiency obtained. If auxiliary exhaust connections to coil are provided, this method of operation should be used whenever possible. If the necessary quantity can not be made when operating on auxiliary exhaust, it may still be possible to operate in this manner when in port or, say, two weeks out of four, operating the remainder of the time in double effect on live steam, or operating part of the plant on auxiliary exhaust and part on live steam. It is more economical to operate in single effect on auxiliary exhaust than double effect on live steam. Attention is called to the fact that the normal working pressure of auxiliary exhaust on vessels having turbine auxiliaries exhausting into this line is 10 pounds gauge, with an allowable maximum pressure of 15 pounds gauge. On vessels having no turbine-driven auxiliaries, and where the personnel is experienced, it is permissible to boost the auxiliary exhaust to 25 pounds gauge, if necessary, in order to produce the required amount of water when evaporators are operating on auxiliary exhaust.

It is most desirable to operate the evaporators at a steady daily output and not to force clean evaporators at a high rate and allow dirty evaporators to run at a low rate. Steady and controlled capacity can easily be obtained by use of an orifice or nozzle in the steam-supply line and by this method only, unless the steam pressure in the first-effect coils is constantly adjusted by experienced operators to correspond with output. This method of operation is fully described in the last pages of this pamphlet, and engineer officers are advised to give it a trial. All necessary fittings can easily be made and installed by the ship's force. Attention is called to the fact that when operating with orifice, the coil pressure will tend to rise to a point above relief valve setting if for any reason the rate of condensation of coil steam is checked, either by water getting low in the shell or by drainage becoming stopped. When using orifice, the coil relief valve must be in particularly good working order. When operating double effect on live steam, if possible, run at rated capacity steadily, i. e., 25 gallons per square foot heating surface for horizontal shell and 60 gallons per square foot for vertical shell type. Other things being equal, the most economical method of operating is to endeavor to maintain a steady daily output which will meet the required average daily consumption. The expenditure from ship's tanks, while it does vary from day to day, is fairly steady for weekly consumption. The make-up feed will be greater at sea than in port, and at sea will vary directly as the speed. The amount of cruising to be done for the week is usually known in advance, and one can, knowing this and the average weekly ship's tanks expenditure, determine on a daily capacity for the week which will take care of this expenditure. The ship's tank capacity is usually about two or three days' expenditure. A good rule is to endeavor to prevent the amount on hand in ship's tank falling below 50 per cent of capacity and reserve feed tanks 25 per cent, and to have the reserve feed tanks as nearly full as possible before getting under way. The amount of water in reserve feed tanks should never fall below 25 per cent of capacity. If a long stay in port is contemplated the daily capacity necessary will be low, and the filling up of the reserve feed tanks, if low on anchoring, should be spread out over a reasonable period. This must, however, be guided by the military requirements of the service and sufficient reserve feed always maintained for any possible emergencies.

If the number of men available permits, it is desirable to operate for full 24 hours. Particularly when the ship has coal-burning boilers, it is advisable to run the evaporators when getting under way and on coming to anchor. This assists the handling of the steam when warming up or disconnecting boilers.

When anchored in a river or harbor where on ebb tide the water is materially fresher than on flood and full 24-hour operation is not required, run evaporators only on ebb tide in order to reduce scaling up and decrease the rate of increase in salinity. This will prove to be most economical, except where the harbor water is impure, when it will be necessary to run on flood tide only.

4. **Starting.**—To start up a plant with evaporators empty and all pumps secured, proceed as follows:

(*a*) Start feed pump, distilling condenser circulating pump, fresh-water pump slow speed, and, if fitted, distilling condenser air pump.

(*b*) Fill shells of evaporators up to two-thirds working level.

(*c*) All vapor valves to be used should be wide open and kept there. It is not necessary or desirable to build up a shell pressure before opening shell vapor valves, the only exception being as noted under 6 (*c*).

(*d*) Crack steam root valve, warming up lines by passing steam into coil. Gradually open steam valve wide after line is warmed up. If using orifice in steam line, maintenance of proper pressure is now automatic while water is in the shell. If using reducing valve, control coil pressure to proper amount with evaporator throttle by hand, keeping reducer set at maximum pressure likely to be used (relief valve setting). If using auxiliary exhaust, open valve wide.

(*e*) Regulate coil drain valve so that a water seal will be maintained in seal glass.

(*f*) Gradually raise water level in shell to the maximum that can safely be carried at the rate of evaporation desired without danger of priming.

(*g*) See that all entrained air is blown out of evaporator coils, traps, highest point of feed line, distillers, and feed heaters (when operating with gauge pressure on shell) and leave air cocks cracked so that air will be blown off as it accumulates, this being desirable even at the sacrifice of a little steam which is lost.

(*h*) When in full operation, adjust speed of distilling condenser circulating pump so that fresh-water discharge from distilling condensers will be about 100° F. Care must be exercised not to put excessive pressure on distilling condensers either by using fire main pressure or by choking down too much on overboard discharge when feeding the shells with pressure on overboard discharge from distilling condensers. Distilling condensers have been ruined through neglect of this point.

(*i*) If fitted, and when using continuous blow down, start brine pump or adjust continuous blow valve so as to maintain correct density in shell.

(*j*) When using intermittent, complete, or partial blow, in starting up after blowing down, all of the above points that are applicable should be given attention. (*c*) is modified, when using complete blow down, in that the vapor valves are opened slowly as soon as the bottom blow is closed. (*d*) is modified by turning steam on coils quickly when cracking off scale.

5. **Feeding.**—Once the evaporators are in operation, the feeding must be maintained at a steady rate. The rate is dependent on the capacity at which the evaporator is being operated. Sudden raising of the water level or a too high level will cause priming. The level of the water in the shell must be the highest that can be held and still prevent the carrying over of water particles into the distilling condensers with the fresh-water vapor. It is most uneconomical to attempt to dry the vapor by heating it with uncovered coil surface. Exposed parts of coils scale up quickly and are a direct loss of working heating surface. The water level depends on the capacity at which operating, maximum brine density, the carefulness of installation of baffles and skill of personnel. The level is higher the less the capacity (within limits) and brine density, and the greater the skill of personnel and carefulness of installation of baffles.

Due to the turbulence of the surface of the water in the shell, the real water level is always a little higher than that shown by the gauge glass, usually 3 inches in horizontal shells to 6 inches in vertical shells (at full capacity).

The internal feed pipe should have holes drilled in it (total area equal twice the area of pipe) so as to distribute the feed equally to all parts of the bottom of the shell and the holes should be arranged to direct the feed downward or horizontally toward center of shell but not upward.

Some makes of evaporators are fitted with automatic feed regulators to maintain a constant water level.

The suction for feed pump should always be taken from the distilling condenser overboard discharge pipe.

On modern installations, except in small auxiliary vessels, feed-water heaters are usually installed for heating the feed first with the vapor and next with drain from the first effect coils.

With evaporators which maintain a vacuum on shell the feed pump may be shut down and by-passed after the plant is started.

6. **Blowing or Brining.**—Sea water contains about $\frac{1}{32}$ part by weight solid matter. As the sea water is distilled in the evaporator, the solid remains and further increases the proportionate part in the new water pumped in to replace that distilled. It is common to speak of the water in shell (the brine) being of $\frac{1}{32}$ or $\frac{2}{32}$, etc., salinity, meaning that $\frac{1}{32}$ or $\frac{2}{32}$, etc., part is solid matter. The salinity may be ascertained by use of a salinometer (described later). The maximum salinity allowable is $\frac{3}{32}$, and this *must not be exceeded* no matter what system of brining is used. The shell salinity may be reduced to as low a maximum as $\frac{2}{32}$ when urgent need for increased output is necessary at a sacrifice of efficiency. High shell salinities will (*a*) reduce capacity (with constant coil pressure) and vice versa if salinity be lowered, capacity will be increased; (*b*) cause rapid scaling up of coils; (*c*) increase tendency to prime; and (*d*) cause rapid corrosion of interior parts due to liberation of acid. Therefore, it is necessary to blow or pump out some or all of the water either at intervals or continuously. An additional reason for blowing is to rid the shell of some of the accumulation of cracked-off scale.

There are three methods of blowing:

(*a*) Intermittent complete blow down.
(*b*) Intermittent partial blow.
(*c*) Continuous blow.

(*a*) To carry out intermittent complete blow down, proceed as follows, the evaporator being in operation:

Close vapor valve and raise shell pressure to about 25 pounds gauge. If using in the coil vapor from another evaporator or auxiliary exhaust, close this supply and admit live steam to coil.

Open bottom blow wide—open quickly.

Immediately thereafter close steam to coil.

Allow brine to blow out until shell pressure reaches about 5 pounds gauge, then close bottom blow quickly.

Then start up as outlined in paragraph 4 above, being careful to have low water level at start except when cracking scale as indicated below.

No matter what method of blowing is used, *at least twice in 24 hours* operation, crack scale off coils by following operation: Fill shell quickly up to *level* of top of coils and turn steam on coils rapidly (about 40 pounds pressure). This will expand the tubes suddenly (due to rapid heating) and crack off the majority of the scale. It is more successful with coiled tube types than with straight tube types. Then, in about five minutes, reduce steam pressure and operate as before. (Until water level is reduced to the proper point by evaporation be very careful not to prime.) It is best to by-pass the feed heater while filling the shell in order to have cool water.

When using this method, the blow should be given when the salinity of the brine reaches $\frac{3}{32}$. The interval between blows depends on the rate at which operating. It can only be found by taking the salinity of shell water with salinometer (described later). It is advised to put a column in evaporator log for entry of brine density just before blowing. In Navy type horizontal shell evaporators operating at rated capacity on clean coils, the salinity increases at the rate of $\frac{1}{32}$ per hour. In vertical shell types, the brine capacity is so small compared to the rate of distillation and the salinity increases so rapidly that this method of blowing is impracticable and methods (*b*) or (*c*) (preferable) must be used. Method (*a*) is *necessary* where pressure *carried* on shell is below that required to force brine out against sea pressure, when a brine pump is not installed.

(*b*) Intermittent partial blow consists of blowing down a certain number of inches of shell water at regular (and frequent) intervals. The method is similar to (*c*) in all respects, except that the brine salinity is kept between certain limits and not at a fixed quantity. The high limit is fixed at $\frac{3}{32}$ and the low limit may be anything desired by the ship, except that it should not fall below $\frac{2}{32}$ after blowing. The amount blown down is dependent on rate of evaporation and interval between blows. If the fresh water is measured in tanks, the following is a convenient method of blowing; determine the number inches height in shell from working level down, which is equivalent to the volume of one fresh water tank, then for each three tanks of fresh water made blow down the volume equivalent to one tank. Operating double effect, blow high pressure and low pressure on each six tanks distilled. It is preferable to blow both at the same time or one right after the other, materially reducing the steam pressure on high pressure and choking down on low pressure vapor valve while blowing. When vapor valve is opened, see that it is done gradually. If the tanks have a greater capacity than that portion of shell covered by gauge glass a proportionate amount of the tank's volume can be used as basis for the calculation. The salinity of the brine must be checked by salinometer at least once for each 100 gallons of fresh water distilled and a sample of brine taken just before blowing. If brine shows above $\frac{3}{32}$, a heavier blow than usual must be resorted to in order to insure that at next blow the brine will not exceed $\frac{3}{32}$ in density. Attention is called to instructions above about cracking scale which must be carried out.

(*c*) Continuous blow consists in *maintaining* a constant salinity of brine by allowing a definite leakage of water from the shell. This may be accomplished either (when gauge pressure is held on shell) by cracking the bottom blow valve or ~~by using~~ a small by-pass around the valve or (when vacuum is held on shell) by taking suction on shell with a brine pump. If by-pass is used, it should be tapped into shell about 1 foot vertically above center of bottom blow connection. The salinity of the brine must be taken with salinometer at least once each hour of operation, and should be recorded in the evaporator log. The salinity must not exceed $\frac{3}{32}$ nor be below $\frac{2}{32}$. If salinity is kept below $\frac{2}{32}$, the heat loss in water blown overboard is excessive. If density exceeds $\frac{4}{32}$ serious corrosion of both piping and fittings will result. An ideal arrangement is to have the salinometer pot arranged so that there is a very small flow of brine through it discharging into bilge and in which the salinometer can be floated giving continuous reading. However, it is to be noted that the temperature may not correspond with one of the scale temperatures marked on the salinometer and the correction for temperature must be known. Also there should be good circulation in the pot, but the quantity flow may be very small and spilled to bilge. Attention is called to instructions under (*a*) about cracking scale which must be carried out. It is not recommended that intermittent blow be used on second effect while continuous blow is in use on first effect. This might be attempted when the pressure on second effect shell with vapor valve wide open is less than the pressure required to blow brine against sea pressure, and in this event, it is better practice to choke down on vapor valve until required shell pressure is attained. This is recommended reluctantly, as choking down on vapor valve reduces capacity (for set coil pressure) and economy, but in this particular case it is more advisable than to risk the dangers of priming caused by mixing intermittent and continuous blow.

Several types of evaporators in use to-day are provided with handholes in shell for removing loose scale without pulling coil. If the twice a day complete blow for cracking scale is properly carried out, and after every three or four days of operation the loose scale is removed through the handholes, the intervals between hand scalings may be greatly lengthened.

7. **Coil and Shell Pressures.**—The pressure required in the coil depends upon the capacity desired and the condition of the coil as regards scale. It is best not to assign definite pressures, but rather to assign a capacity, which then will vary with amount of scale on coil. The following table gives an idea, for double-effect operation, clean coils, of the relation of pressures and gallons fresh water distilled per square foot of working heating surface in the coiled tube type of evaporators.

Gallons per day per square foot heating surface.	Coil pressure, first effect (pounds gauge).
30	8.5
60	19.6
90	34.7
120	52.7
150	74.3

As the coils become encrusted with scale, these pressures must be increased to maintain a certain capacity.

In starting up, the coil pressure on first effect should be built up gradually to the point desired, else priming is likely to occur. When using reducing valve on steam line, do not readjust the valve for various desired pressures on coil, but rather leave it at a definite maximum setting and control coil pressure with hand-stop valve. If using orifice in the steam supply line, the weight flow of steam will remain constant and coil pressure will be adjusted automatically *except when there is little or no water in the shell,* when it will rise to steam-line pressure (this must be guarded against when using orifice). A steady steam supply is necessary in order to run at good capacity and at same time make good water. It is not economical to attempt to raise the shell pressure by closing down on the vapor valve. The evaporator is designed to produce water of less than 2 grains chlorine per gallon at rated capacity with vapor valve wide open. The first-effect shell, second-effect coil, and second-effect shell pressures should be allowed to adjust themselves to what they will with all valves wide open (water seal maintained on second-effect coil drain) and only the pressure on first-effect coil should be subjected to regulation. If a distilling condenser air pump is installed it should be used, provided priming does not occur, as it lowers the shell pressure of the evaporators discharging vapor direct to distilling condensers and consequently increases economy and capacity.

Shell pressures as low as 20 inches of vacuum are being used. Incidentally, use of vacuum on shell considerably lowers temperature of evaporator rooms as the boiling point of the brine is very much lowered.

8. **Water Testing.**—The distilled water should be tested frequently for presence of chlorine. The frequency of the test must be determined by the engineer officer, having due regard for experience of personnel, capacity at which operating, efficiency of baffles, frequency of trouble with salty tanks, etc. However, when starting up, the test should be made almost continuously until good water is being made. The character of the distilled water is given by the number of grains weight of chlorine (component of common salt) in a gallon of water. Boiler feed water should always be made containing less than 2 grains chlorine per gallon.

Experience has shown that if distilled water tests over 0.5 grain chlorine per gallon the distilling plant is not operating at satisfactory efficiency and steps should be taken immediately to locate and rectify the cause of this unsatisfactory condition.

If chlorine is present in water and silver nitrate solution is added, the two will combine, forming a milky streak in the water. The amount of milkiness is sometimes used as a rough judge of whether or not the water is fit for use. This method is not advisable. It is much more satisfactory to make up a rough testing set employing the method used for testing boiler water. All the gear that is needed is a large-mouthed bottle of about 100 c. c. capacity with a strip of adhesive plaster at the 50 c. c. level, a small bottle of potassium chromate indicator and one of silver nitrate (about 25 c. c.), and two eye droppers. It is assumed that the pamphlet on testing boiler water is available, which describes the method in detail. Use about 5 drops of the chromate as an indicator, using 50 c. c. of test water, 1 c. c. silver nitrate indicates 1 grain chlorine per gallon. The ordinary eye dropper is of about 1 c. c. capacity, but as the droppers are cheaply made there is some variation. Graduate the dropper by drawing in 1 c. c. liquid and filing a mark on the glass at the 1 c. c. level, then slide the bulb on or off until one squeeze will just draw in 1 c. c. of liquid. If the limit on chlorine is set by the engineer officer at 2 grains per gallon, and if the sample does not turn reddish brown when 2 c. c. of nitrate are added, the water should be rejected. The men should be instructed to always wash out the sample testing bottle with some of the water to be tested. Only a small amount of nitrate should be carried at the evaporators as it becomes weakened very rapidly when heated.

TROUBLES AND LOSSES.

9. **General.**—The fuel expenditure for the production of fresh water aboard ship ranges from 20 to 50 per cent of the port daily expenditure. In no part of the Engineer Department is there more opportunity for producing concrete results in fuel saving. This can be done by proper operation, special attention to heat losses likely to occur, and a general checking up of the plant by the engineer officer to see that the installation has been correctly installed and manufacture by ship's force of some of the heat-saving devices mentioned in this pamphlet. Coil drain heaters, drain collectors, water seals, approved improvements to baffles, etc., have been manufactured with the ordinary facilities for manufacture on battleship or destroyer repair ship. However, engineer officers are cautioned not to alter the installation unless with approval of or on instructions issued by the Bureau of Engineering.

10. **Draining.**—It is essential that steam be prevented from blowing through the coil drain. A water seal, trap, or drain collector is always fitted on coil drain. This device should properly be outside the coil system and below the coils to insure all parts of coil heating surface being drained clear of water. Portions of coils filled with water are a dead loss of working heating surface and reduce capacity with given coil pressure. Sometimes a gauge glass is also installed on the coil itself, but this is only for an indicator when the water-seal device is not operating, and, in ordinary operation, water should never appear in this glass. It is never installed with coiled or U tubes, as there is a difference in pressure between supply and discharge headers and the correct level would not be indicated; in fact, the glass would probably always show full of water. On the Griscom-Russell type there is a standpipe tapped into the bottom header and fitted with a gauge glass and air cock on top. This standpipe is only for the purpose of indicating a rise in the level of drain water and to trap air, and must never be connected to the top manifold. When using live steam or auxiliary exhaust as coil steam, the coil drain from that evaporator must be led to the feed tank direct, otherwise the fresh water made will be polluted with the boiler steam condensed.

11. **Priming.**—Priming is a loss due to the fact that the salty water produced is wasted. It is caused by:

(1) Too great a coil steam pressure, giving overload capacity.
(2) Building up coil pressure too quickly.
(3) Sudden opening of vapor valve with pressure on shell.
(4) Unsteady steam pressure in coil.
(5) Water level not carried at proper point (too close to bottom baffle, allowing water to be thrown up between baffle opening, in case of all except Reilly submerged tube type when too low level is the cause).
(6) Unsteady feed.
(7) Salinity of brine too high.
(8) Unsteady drain discharge:

For steady operation in a given installation, priming will occur when the velocity of steam liberated from the surface of the water rises above a certain amount. The velocity varies with both the weight of vapor produced (capacity) and the shell pressure. As the shell pressure is reduced the volume of a pound of vapor increases rapidly. The volume of steam passed through a square foot of liberating surface of the water is a very high figure in evaporators compared to that designed for in boilers, and consequently the method of baffling must receive closer attention. For example, the disengaging velocity of steam in feet per minute in a Yarrow destroyer boiler at high capacity (16 pounds steam F and A per square foot heating surface, 255 pounds steam pressure) is 60 and for Reilly No. 24, second effect evaporator (at rated capacity 45 per cent in low pressure, shell pressure, 2 pounds gauge) is 406 and in Reilly No. 16 second effect 168. It is not economical to attempt to dry the vapor by installation of superheater or by keeping a low-water level. Attention is particularly called to the fact that if the water level is carried above the top of the coils the liberating water surface is doubled in horizontal tube types of evaporators. In the Reilly type where a crown baffle is installed over the coils, priming will occur if the water level is lowered so that it comes near to the bottom edge of the baffle, and this is particularly noticeable when the vessel is rolling.

12. **Air.**—The question of air collection in various parts of the apparatus must be given attention. It is not believed that the seriousness of this trouble has been appreciated. Air is heavier than steam, and when steam, air, and water are present in a tank or pipe system the air always settles between the water and the steam. Air enters various parts of the system with entering steam and water. Air will accumulate at the following points:

(1) Coil drain trap or water seal.
(2) High point of feed line.
(3) Water side of distilling condensers.
(4) Feed heaters.
(5) Coil drain heaters.

Air cocks must be installed at the points where air accumulates and the air should be blown off at frequent intervals or preferably the cock kept cracked so that a little vapor or water is blowing off constantly, insuring air drainage. The Reilly type evaporator is fitted with an air collector on drain line. Often, inability to obtain rated capacity in an evaporator is due solely to failure to drain off accumulations of air.

13. **Salinity.**—A very large loss of heat will occur, if, when using continuous blow method, too low brine salinity is maintained. Also see paragraph 16.

14. **Salty Distilled Water.**—Too high chlorine in the distilled water may be caused by priming or by a leaky distilling condenser or fapor feed heater. A leaky distilling condenser is located by testing the water from each distilling condenser in use, separately.

Bad salting up of feed tanks may occur from leaky coils or stays in horizontal tube type. The salt water entering the coil when a complete blowing down is given, when the shell pressure is greater than the coil pressure. A leaky coil drain heater will also salt up feed tanks.

15. **Oily Water.**—Oily distilled water will be caused by coil leakage into shell space, if boiler steam is oily, or at any rate the water will have an unpleasant taste. This may also be caused by leakage of valve on drain line separating drains from first and second effect evaporators, or by running drain from a coil using live or auxiliary exhaust steam into distilling condenser instead of to feed tank. The men must be cautioned not to use tallow on gaskets in fresh water joints as this will cause oily water and may be very difficult to trace. If the evaporators are shifted

from single effect operation to double effect, run a few tanks of the water first made to reserve feed tanks as the second effect coil drain may have an unpleasant taste for a short while.

16. **Corrosion.**—The interiors of evaporator shells, if made of iron or steel, are liable to serious corrosion. The corrosion shows itself as a heavy, red dust, and in many cases a shell is corroded through in the course of two years' use. Corrosion is worse just above the water line.

Conditions in an evaporator are such as will stimulate corrosion. Sea water contains magnesium chloride which, when heated, decomposes, liberating hydrochloric acid, which causes rapid corrosion of iron and steel. It has been found by experiment that, when the brine salinity is allowed to go above $\frac{4}{32}$, large quantities of the acid are given off and would cause serious corrosion of a steel shell or baffle in a very short time. In addition the the hydrochloric acid danger, there is in sea water considerable amount of air and some carbonic acid gas. These also cause serious corrosion, but this can not be prevented. Furthermore, when the shell and fittings are made, some parts of iron or steel and others of composition, corrosion takes place from electrolysis (battery action, decomposing the steel or iron).

In order to check corrosion of steel shells, zincs are installed and the steel or iron parts are given cement wash. Sometimes shells are galvanized on the inside, but the galvanizing lasts only a short time. Also, salt scale is allowed to remain on underwater parts of shell (when iron or steel) and this forms probably the best protection. This scale should not be allowed to cake up very thick, but the underwater parts of shell should not be scaled to the metal except when giving a complete overhaul. Upper portions of shell, when of steel or iron, are where corrosion is most rapid, and these parts must be kept covered with cement wash. Some ships have had difficulty in making the cement adhere properly. However, it will adhere if the following method is used: Scrape off all foreign matter and then wire brush clean, apply good grade Portland cement (sift the cement carefully with fine mesh sieve) with a wide flat brush, cement mixed to consistency of paint. Apply five coats, allowing each to dry before applying the next. Then (important) fill the shell with cold water and allow cement to harden for 24 hours. The wash should be applied to all parts that are made of iron or steel, as shell, baffles, and stay rods. When overhauling, do not remove cement which is adhering properly.

When the shell is built up of two or more plates, at overhaul examine the joints carefully for corrosion; also on old-style vertical evaporator steam domes, examine the metal at sharp bends, as often the metal has been overheated or not properly worked and defects have developed. For corrosion of piping see paragraph 26.

OVERHAUL.

17. **Scaling.**—The interval between hand scalings of coil should be based not on straight time or hours operation, but on gallons water made, the density of sea water, and the efficiency of "cracking scale" and removal of loose scale by bottom blow. In later types of vertical evaporators a handhole plate is provided for pulling out loose scale without pulling coil. With the coil tube type, if the operation of "cracking

scale" is carefully and consistently attended to, hand scaling will only be necessary at general overhaul. Scale will crack from coiled tubes more readily than from U tubes, and from U better than from straight tubes. The indication of when scaling is necessary is given by its requiring an excessive coil pressure to make rated capacity.

If running at rated capacity, it will be found advisable to pull coils and scale by hand at following intervals, for the various types of evaporators:

Type of tube.	Hours of operation interval between hand scalings.
Straight	300
U	500
Coiled	700

Before pulling coils for hand scaling, always fill shell to level above top of tubes and heat water to boiling point. Then shut steam off coil and allow to stand until cool (not cold). Empty shell and pull coil. It will be found that the scale will be quite soft and will come off easily. The scaling should now be proceeded with at once.

Tubes are scaled with scaling bars and hammers, principally by jarring the tubes, but care must be used not to dent the tubes, particularly with coiled tubes. If a coil gets badly dented so as to materially reduce area for steam flow, it should be disconnected and put under a water pressure sufficiently high to bulge out the dents.

Salt scale should all be removed from shell once in six months. At other times only remove very thick layers.

When coils are pulled for scaling, the zincs should be cleaned off and, if more than one-third decomposed, should be renewed. When installing zincs, be sure there is good metallic contact between the zincs and the parts to which they are secured. It is advised to use red lead putty between bolt head and zinc and between zinc and the washers under it, so that the joint will be water-tight.

The bottom blow line should be entirely removed once in three months and the salt deposit removed. Cases are on record of the bottom blow being completely stopped up with salt scale deposit.

18. **Valves and Baffles.**—Whenever the evaporator is shut down for hand scaling of coils, the bottom blow, brining valve, and feed check valves, the dry pipe, internal feed line, and all baffles should be examined. The valves are liable to rapid corrosion and errosion of seats and disks. The holes in dry pipe are liable to become stopped by salt deposit, reducing area for steam flow, and in bad cases reducing the possible capacity of the evaporator. The baffles should be examined for excessive corrosion and for their proper and secure installation. Considerable laxity exists in proper installation of the baffles in accordance with approved plans and usually trouble in making good water can be traced directly to this fault. Joints which are supposed to be tight and prevent vapor leakage in that direction had best be made up with fiber or asbestos sheet packing. When baffles are badly corroded,

have them renewed at once by ship's force or repair ship. If space is available carry at least one spare set of baffles on hand.

19. **Heaters.**—The salt-water side of tubes in coil drain and vapor feed water heaters will accumulate a deposit which should be removed about once a quarter. This deposit is particularly bad when ship is in the Tropics using water containing minute coral particles which deposit when the water is heated to even low temperatures (not boiled). If a heater is leaky, simply secure the water connections and by-pass the feed side until the heater can be overhauled; no harm will be done the tubes by allowing vapor to pass through the heater though a few may require rerolling.

TESTS.

20. **Coil.**—The evaporator coils should be tested hydrostatically to the pressure at which relief valve is set, whenever they are removed for hand scaling. The test should be applied after scaling. It is preferable to use fresh water for test, for, if salt water is used, it is difficult to flush out well with fresh afterwards. In operation, coils should be tested at complete blow down by taking sample of coil drain water when shell pressure is greater than coil pressure. If coils are leaky, coil drain water will be salty.

Shell.—With iron or steel shells, the point most affected by corrosion should be drill tested once a year or when there is doubt as to the strength of the metal. Pressure test of shell should only be given when there is doubt of the strength, and then, the pressure should not exceed 25% in excess of relief valve setting.

Relief valves.—The shell and coil relief valves *must* be tested daily by lifting them by hand and weekly by lifting them by steam. The most opportune time to test by steam is when giving a complete blow down.

Distilling Condensers.—Distilling condensers can best be tested by making separate chlorine test of fresh water passed through each. If tested hydrostatically, use only fresh water on vapor side and prescribed test pressure must not be exceeded.

FITTINGS.

21. **Separators.**—Separators are installed on the vapor lines of the first effect to coil of second effect and sometimes from shells to distilling condensers. In ordinary operation there should be practically no drainage from them, except from condensation. The drains from separators should be lead to either bilge, low-pressure evaporator shell, or feed pump suction, or as shown on type plans.

22. **Superheaters.**—Superheaters have been installed on some types of evaporators but are not economical, and, if baffling is properly designed and evaporator not forced to too high capacity, they are not necessary. On at least one vessel, one low-pressure evaporator was used as a superheater, the shell being cut in on to the vapor line and steam kept on the coils. This is prohibited. It is most uneconomical and the shell of an evaporator so used will be rendered useless, due to corrosion, in a very short time.

23. **Feed Heaters.**—Vapor feed heaters using the vapor from the low-pressure evaporators are installed in nearly all recent plants. They should be piped up to be in *series* on the vapor line. Occasionally the feed heaters are arranged to act as separators as well. Heaters are designed so that the vapor passes through the tubes and the salt feed is on the outside. The vapor feed heater should heat the feed to within about 20° of the vapor temperature.

In addition to vapor feed heaters, coil drain heaters are sometimes installed, where the feed water after passing through the vapor feed heaters, is further heated by the first effect coil drain. This type of heater can readily be made by ship's force. It should always be used as it prevents flashing of drains in feed tank as well as saving heat.

With proper operation, the combination of these two heaters should form a 20 per cent saving.

24. **Distilling Condensers.**—Attention is called to the change in appellation of this fitting, the old name being "distiller." The specifications provide for horizontal shells for low-pressure plants and vertical shells for high-pressure plants. In both, the water passes through the tubes and the vapor is on the outside of the tubes. For high-pressure plants, they may be single or double flow design on circulating water side. The vapor should enter top and water enter bottom discharging at top for single flow types and water enter and discharge at top for double flow types. When straight tubes are installed, means must be provided for expansion. With cast-iron shells, this is done by fitting the bottom tube sheet with a stuffing box expansion joint so that it can expand independently of shell. The most frequent cause of leaky tubes (straight) is the freezing up of this expansion joint. The movement of the joint should be watched. When shells are made of brass or copper an expansion flange is fitted. Zincs are installed in water chambers. Baffles are usually installed in circulating water chambers to insure the outer tubes getting full share of circulating water. On existing plants, particularly those that have been long in operation, these baffles should be checked with drawing to insure that they are properly installed. It is important that an air cock be installed on top of salt water side. This should be kept cracked, overflow piped to waste through open funnel, funnel to be above point where air cock taps into distilling condenser. A vacuum breaker is installed on vapor side. The practice of admitting air to vapor side is not recommended as it will materially reduce the capacity of the distilling condenser and when shell pressure is below atmospheric, the connection must be blanked off. When using distilling condenser air pump, all possible air leaks into the system must be stopped. It is necessary for success with this method to put air test of about 10 pounds. gage on the entire vapor system for test of pipe joints, valve stem stuffing boxes, etc., for air leaks. This test should be made weekly. With straight tubes, the efficiency of distilling condensers may be improved by installing thin sheet brass whirler strips inside the tubes. The tubes should be cleaned out twice a year.

25. **Pumps.**—The following pumps are found in distilling plants, some pumps only appearing in the more modern, large installations:

Name.	Use.
Evaporator feed pump	For introducing water into evaporator shell. Sometimes feed is taken by pressure from distilling condenser overboard discharge, from fire main, or from flushing system.
Distilling condenser circulating pump.	For providing circulating water for distilling condensers. Sometimes connections are made for supplying water from fire mains or flushing line.
Distilling condenser air pump.	For lowering the pressure on evaporator shells by taking suction on fresh water discharge side of distilling condensers.
Fresh-water pump	For boosting fresh water made, from measuring tanks or meter to ship tanks.
Brine pump	For pumping brine out of evaporator shell where pressure is too low for pressure blow.

Notes on the care and operation of these pumps can be found in the bureau pamphlet on "Pumps." (N. Eng. 83.)

26. **Piping.**—Salt-water piping when conveying hot salt water is subject to rapid corrosion unless properly protected. This corrosion shows itself in the pitting of the copper piping, especially in localities where the piping has been worked, as at ells and brazed points. The following is done to protect the piping against this corrosion:

(*a*) The interior is protected with coating of a solder of lead and tin or a lead tube is expanded into the pipe. The latter is efficient, if the lead layer is of even thickness, but it does not usually expand equally at all parts of the circumference of the tube and hence very thin parts or even holes occur.

(*b*) Zinc boxes are located in the lines. The zincs should be inspected monthly. The British practice is to install, instead of zinc boxes, short lengths of cast-iron pipe in accessible places. The cast iron corrodes in place of the copper, but the cast-iron spools are made extra heavy and in any event can be renewed at small expense. This is probably the most effective method of preventing corrosion of the copper piping.

(*c*) Install air chamber and air cock at highest points of lines, allowing air cock to blow continuously. This rids the line of air and hydrochloric acid gas which is the cause of the corrosion.

The bottom blow line and coil drain lines should be led in as straight a lead as possible and such bends as are unavoidable should be of large radius.

27. **Measuring.**—Some method of continuously measuring the output of the evaporators and not depending on ship or reserve feed tank soundings is essential for intelligent operation of a distilling plant. Columns should be provided in the evaporator log for hourly entry of water made and an office record should be kept of water distilled daily by each evaporator.

In large installations there is usually an automatic recording meter constructed on the volumetric principle. "Cochrane" precision meters are in use for this purpose. When erecting one of these meters be sure that the vent to atmosphere is installed and kept open, otherwise the floats will be damaged when using distilling condenser air pump. These meters occasionally operate erratically when ship is rolling, the floats tripping valve gear before tank is full. The best cure for this is to tighten valve stem and float stuffing boxes to make gear stiff in operation.

On other ships a measuring tank is used. The tank is divided into two compartments. For destroyers each compartment should have a capacity of 50 gallons and for capital ships 300 gallons.

28. **Gauges and thermometers.**—The following gauges and thermometers will be found necessary for proper operation of distilling plant:

Pressure gauge for line steam pressure.

Compound gauge on shell of each evaporator.

Pressure gauge on coil of each evaporator.

Compound gauge on vapor line near distilling condensers.

Thermometer, permanent, in feed line between last feed heater and entry to shell of each evaporator.

Thermometer, permanent, in overboard discharge from each group of distilling condensers.

Portable thermometer for temperature of water, in measuring tanks. With meter, it is best to install thermometer permanently in the line.

Portable thermometer for use with salinometer.

29. **Salinometer.**—The salinometer is an instrument for measurement, on the principle of a float, of the degree of salinity or concentration of the brine. It is a hollow glass or metal vessel weighed with shot at the bottom, and having a projecting stem which is graduated in two or three scales to read the salinity for various temperatures of the brine, usually 180°, 190°, and 200° F. The graduations are marked as 32ds., from zero to about 5. Sea water is about $\frac{1}{32}$ saturation and the point where no more salt can be dissolved into solution would be approximately $\frac{11}{32}$.

A pot must be provided for holding the sample. The pot must be amply deep so that there is no danger of breaking the bottom of the salinometer when putting it into the pot. To use, draw off pot full of sample, put in thermometer, allow sample to cool to one of the scale temperatures, put in salinometer and read degree of salinity. When salinometer is removed, wipe off all moisture, as accumulations of salt or dirt on the salinometer will cause it to give too low readings.

30. **Air cocks.**—Air cocks must be fitted at the following points:

(*a*) Bottom manifold of coil or on drain line before entering trap.
(*b*) High point of feed line.
(*c*) All traps.

31. **Drain pots.**—In order to obtain full benefit of all the coil-heating surface, it is necessary to install a trap or drain pot (drain collector) on the drain from the coils and at a point where the top of the drain pot will be below the bottom of the coils. It is erroneous to suppose that, because there is a definite flow through the coils, the drain pot may be placed at a level above the bottom of the coils. In practice, it is found necessary to install the drain pot with the assumption that the coil drainage is by *gravity* only.

THERMAL PRINCIPLES AND ORIFICE OPERATION.

32. A short discussion will here be given of the thermal principles involved in distilling water, which should be helpful in giving officers better judgment in directing operation, and, perhaps, lead the way to further improvements of the plant in both design and operation.

An evaporator is primarily a "heat transfer" apparatus—that is, heat is supplied to the coils by use of steam and is transmitted through the metal of the coils and through the scale to the water which is boiled, giving off fresh vapor and leaving behind the salts and other solid matter. The ability of the coil to transmit heat is measured by the "heat transfer coefficient." By definition, the heat transfer coefficient is equal to the British thermal units (B. t. u.) transferred through the coil per hour per square foot of surface per degree of temperature difference between the mediums on the two sides of the coil surface. This may be expressed by the formula:

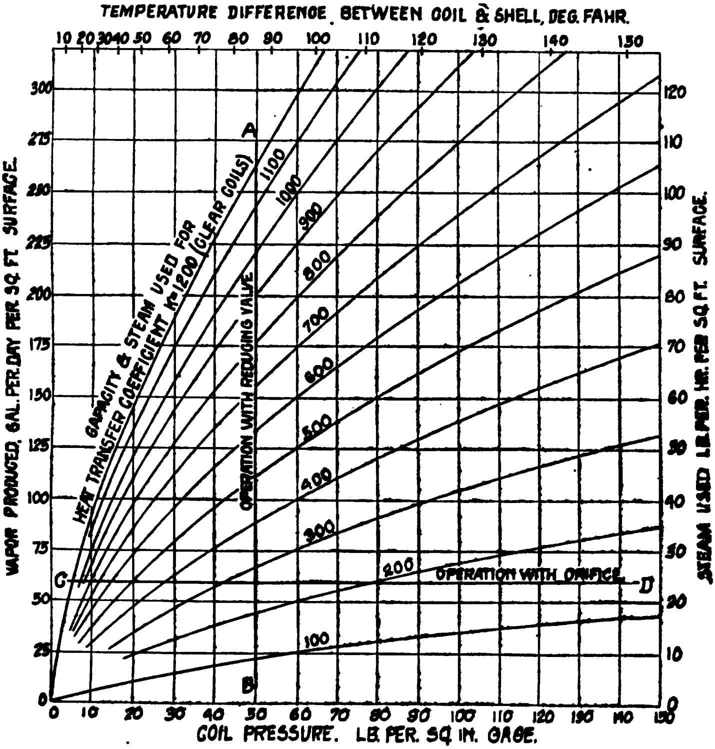
K B. t. u. transferred per hour per square foot heating surface per degrees temperature difference $=\frac{W(H_s-Q_d)}{S\times TD}$.

K Heat transfer coefficient.
W Steam condensed in coils, pounds per hour.
H_s Heat in steam entering coil, B. t. u. per pound.
Q_d Heat in condensate (drain) leaving coil, B. t. u. per pound.
S Evaporating surface, square feet measured on the salt-water side of coils (outside).
T. D. Degrees difference between the temperature of the coil steam and vapor steam equals $T_s - T_v$ where T_s=temperature corresponding to coil pressure (see steam tables) and T_v=temperature corresponding to the vapor (shell) pressure.

33. The numerical value of the coefficient for any given set of operating conditions may be computed from the above equation. Physically, the value of the coefficient depends upon a number of factors, which, in the probable order of their importance, are, condition and amount of scale accumulated, salinity of brine, water level, design of coils, vapor pressure, and coil pressure. In a given evaporator, values of K ranging from 1,200 to 100 are possible. One thousand is an average value when the coils are clean and with sea water in the shell, but when scale has accumulated on the coils to a considerable extent, the coefficient drops to 200 or even 100.

34. **Operating Coil Pressure.**—In the practical operation of an evaporator a most important problem is the determination of the proper coil pressure for the production of the desired capacity. The temperature difference required for the production of any capacity may be determined at any time from the heat transfer equation if the coefficient K be known. Having the temperature difference, the coil pressure corresponding to the temperature difference is easily determined. Figure 1 shows graphically the relation between capacity, coil pressure, temperature difference, and heat transfer coefficient for any evaporator operating with vapor pressure of about 1 pound. This diagram may be used to determine any of the factors when the others are known. For example, in operating an evaporator in which the coils are clean, the heat transfer coefficient will be say, 1,200. With a coil pressure of 50 pounds, the capacity produced will be determined at the point A which gives about 265 gallons of vapor per day for each square foot of surface in the evaporator, provided that all the surface is surrounded with brine. As the operation of this evaporator proceeds with the coil pressure of 50 pounds, scale will accumulate on coils and the value of the heat transfer coefficient will decrease and the operation will be along the vertical line AB with constantly decreasing vapor production. If it is known what capacity is desired upon starting

the evaporator with clean coils, the proper coil pressure may be determined from the diagram. As the scale accumulates on the coil the original capacity may be maintained by gradually increasing the coil pressure. For example, the operation may be along a horizontal line such as CD.



SINGLE EFFECT EVAPORATOR.
RELATION BETWEEN CAPACITY, COIL PRESSURE, TEMPERATURE
DIFFERENCE AND HEAT TRANSFER COEFFICIENT

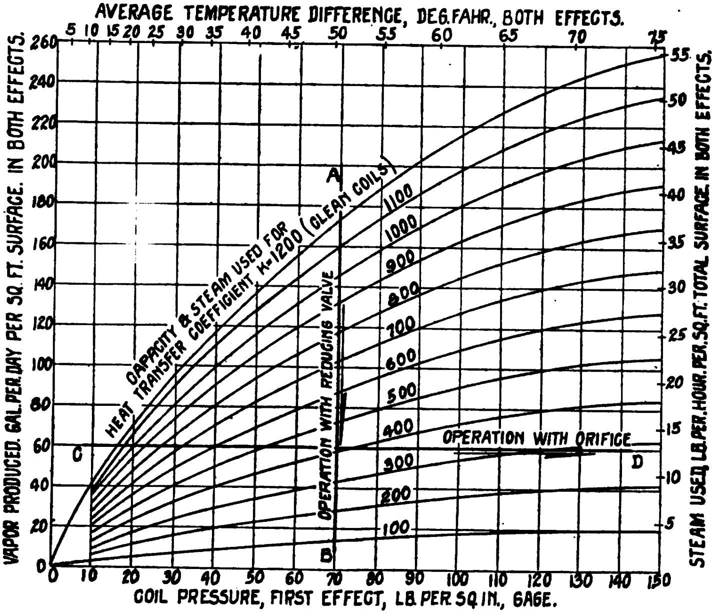
FIG-1

35. Figure 2, shows the relation between capacity, coil pressure, temperature difference, and heat transfer coefficient for double-effect evaporators operating with atmospheric shell pressure on second effect. From this diagram, it is seen that definite relations exist between coil pressure, capacity, and heat transfer coefficient and that in determining

the coil pressure to be used, both the capacity desired, and condition of the coils as regards scale must be taken into account.

36. **Supply of Steam to the Coils.**—Steam may be supplied to the coils of an evaporator by one of the three following methods:

(*a*) Hand control.
(*b*) Reducing valve.
(*c*) Orifice.



DOUBLE EFFECT EVAPORATORS.
RELATION BETWEEN CAPACITY, COIL PRESSURE, TEMPERATURE DIFFERENCE, AND HEAT TRANSFER COEFFICIENT.

FIG-2

It is seen from figures 1 and 2 that for ideal operation at constant capacity, the coil pressure required must be variable. Also, the diagrams show that, when supplying steam to the coil through a reducing valve which maintains constant coil pressure, the capacity will be variable. In choosing between hand control and reducing valve control, each has its advantages and disadvantages. With reducing valve control, if a valve is set so as to maintain, say, 50 pounds gauge on the coils with single-effect operation, the capacity produced when coils are clean will very likely be excessive and produce priming. In order to avoid this priming, very often the water level is carried low in the shell so as to render only a portion of the heating surface effective and thereby reduce the capacity to a safe value. This practice is not desirable, because when operating with a low-water level the exposed portion of the coil very quickly accumulates a heavy mass of scale. In evaporators of submerged tube type, low level will even cause priming.

37. A combination of reducing valve and hand control may be used. The reducing valve is set for the maximum desired coil pressure and, upon starting, the pressure in the coil is reduced by hand to a point which will produce a safe capacity and at same time allow the water level to be carried sufficiently high. Then as the capacity starts to fall off, due to accumulation of scale, the pressures are increased by hand until a pressure is reached corresponding to a reducing valve setting at which point the coil pressure is regulated by the reducing valve and a constant coil pressure is maintained while operation proceeds at a decreasing capacity as scale further accumulates. It is evident that the ideal method of operating the evaporator is at a constant capacity. The only objection to this is that it requires a variable coil pressure, in fact, the figures 1 and 2 show that in order to operate at a constant vapor production, the coil pressure must vary over wide limits, as the accumulation of scale results in a large decrease in the heat transfer coefficient. It is evident that for the production of vapor at a constant rate steam must be admitted to the coils at a constant rate, regardless of the steam pressure in the coils. This follows from the fact that each pound of steam admitted to the coils from the main line contains a certain quantity of heat and upon condensing has the ability of producing a definite quantity of vapor.

38. **Purpose of orifice.**—It so happens that in the steam orifice we have an apparatus which in a most simple manner automatically fulfills the requirements of admitting a constant amount of steam to the coils, and therefore of producing a constant amount of vapor independent of the condition of the coils as regards scale, or the pressure in the coils within wide limits. The reason for this is best seen by noting Napier's formula for flow of steam from a point of higher pressure through an orifice to a point of lower pressure. This formula is given as

$$W=\frac{PA}{70},$$

in which W equals the weight of steam flow through orifice in pounds per second, A is area of orifice in square inches, P is absolute pressure on entering side of orifice, pounds per square inch.

This formula applies when the pressure on the discharge side of the orifice is equal to or lower than the critical pressure, which is 0.58 of the pressure on the entering side of the orifice. With steam flowing into the coils through an orifice, the coil pressure will adjust itself to whatever value is required to produce the temperature difference which will be necessary to transmit through the coil the heat involved in the condensation of the steam. Although this takes place automatically it is well to consider quantitatively the relation between steam flow and coil pressure when the orifice is used. The heat transfer coefficient formula is—

$$K=\frac{W(H_s-q_d)}{S\times T.\ D.}$$

In the orifice method of operation the steam flow W is constant. The total heat in the steam H_s is constant. The heat of the liquid of the condensed steam $2q_d$ increases only slightly with the coil pressure. Therefore $(H_s - q_d)$, which is the heat removed by condensation in the coils, B. t. u. per pound of steam, is also practically constant. The surface S is constant, and K, the coefficient of heat transmission, is variable, depending upon the condition of the coils as regards scale and certain other conditions of operation. The temperature difference may be solved as follows:

$$T.\ D. = \frac{W(H_s - q_d)}{K \times S}$$

Since K is the only variable on the right side of this equation, it is evident that for every value of K there is a corresponding value of temperature difference required. The shell pressure fixes the shell temperature and, with the temperature difference fixed, the coil temperature and coil pressure are fixed. The coil pressure will adjust itself to whatever value is required to produce a temperature difference which will be necessary to transmit heat through the coils.

39. The operation of an evaporator with the orifice would therefore start with a high value of K and relatively low coil pressure. As the operation continues and the value of K decreases, the coil pressure will increase, and, at the same time, the steam flow and therefore the capacity will remain constant. The operation of an orifice applied to a single-effect evaporator may be clearly understood by referring to figure 3. Assuming the orifice of such size as to admit 24 pounds of steam per hour per square foot of surface, the vapor produced will be 60 gallons per day per square foot of surface, if all the steam is condensed in the coils. Upon starting operation with clean coils entirely submerged in brine, the heat transfer coefficient will be approximately 1,200, and operation will start at the point C with a coil pressure of 5 pounds gauge and a vapor production of 60 gallons per day per square foot of surface. If the line pressure is 250-pound gauge, the critical pressure for the orifice will be about 140-pound gauge, so that it is seen that the 5-pound coil pressure is well within the critical pressure and that the steam flow will be constant. As scale accumulates on the coils the operation will automatically proceed along horizontal line CD at constant steam flow, constant capacity, gradually decreasing heat transfer coefficient, and gradually increasing coil pressure. At each instant, the coil pressure adjusts itself so as to automatically correspond to the particular value of heat transfer coefficient existing at that time. The flow of steam through the orifice into the coil will not decrease until the coil pressure has been increased above 140 pounds at the point D, which corresponds to heat transfer coefficient of about 140. A highly feasible arrangement of piping for application of orifice operation to evaporators is shown clearly in figure 3.

40. The orifice method has been adopted in several destroyers with much success. In order to assist in the installation of orifices, the following table has been prepared, giving the sizes of orifices required for the production of various capacities with single and double effect evaporators, and with various line pressures.

TABLE 1.—*Orifice diameters in inches.*

STEAM LINE PRESSURE.

Gallons water distilled per day.	Single effect.				Double effect.			
	150	200	250	285	150	200	250	285
1,000	1/4	7/32	11/64	3/16	3/16	11/64	5/32	9/64
2,000	23/64	5/16	9/32	17/64	17/64	15/64	7/32	13/64
3,000	7/16	3/8	11/32	21/64	21/64	19/64	17/64	1/4
4,000	1/2	7/16	13/32	3/8	3/8	21/64	19/64	9/32
5,000	9/16	1/2	7/16	13/32	13/32	3/8	5/16	5/16
6,000	5/8	17/32	1/2	15/32	15/32	13/32	11/32	11/32
7,000	21/32	19/32	17/32	1/2	1/2	7/16	3/8	3/8
8,000	11/16	5/8	9/16	17/32	17/32	15/32	13/32	13/32
9,000	3/4	21/32	19/32	9/16	9/16	1/2	7/16	7/16
10,000	25/32	11/16	5/8	19/32	19/32	17/32	15/32	15/32
11,000	27/32	23/32	21/32	5/8	5/8	9/16	15/32	15/32
12,000	7/8	3/4	11/16	21/32	21/32	19/32	1/2	1/2
13,000	29/32	25/32	23/32	11/16	11/16	19/32	17/32	17/32
14,000	15/16	13/16	3/4	23/32	23/32	5/8	17/32	17/32
15,000	31/32	27/32	25/32	3/4	3/4	21/32	9/16	9/16

41. Figure 11 shows a recently developed type plan of distilling plant for destroyers.

The diagram illustrates a double-effect distilling plant.

The normal operation will be in double effect with live steam in the first-effect evaporator steam coils. Provision is also made for admitting auxiliary exhaust steam to both evaporator steam coils for operating one or both the units in single effect when there is an excess of auxiliary exhaust steam available.

Both evaporators can be run as single-effect units, using live steam, but operation in single effect on live steam will be used only when there is an emergency requirement for fresh water.

42. Figures 4 to 9, inclusive, show a recently developed type plan of distilling plant for capital ships.

The figures illustrate evaporators designed for normal operation in double effect using live steam and show the maximum number of units it is contemplated ever using as per plant A of table below headed, "Necessary equipment for various size double-effect distilling plants." Similar arrangements for plants B and C, are readily developed from the diagram shown by correspondingly reducing the various units of the equipment.

The normal operation will be in double effect with live steam in the first effect evaporator steam coils. Provision is also made for admitting auxiliary exhaust steam to all evaporator steam coils for operating the units in single effect, when there is an excess of auxiliary exhaust steam available.

It is not intended to operate the entire plant in single effect on auxiliary exhaust steam, as the available auxiliary exhaust would be insufficient. For this reason four, four, or two evaporators is the maximum number to be operated in single effect on auxiliary exhaust at one time for plants A, B, or C, respectively, and the plants are designed accordingly.

The air pumps take suction from only half of the distilling condensers, in order that part of the evaporators can be run with auxiliary exhaust steam and the others with live steam at the same time.

The various systems of piping are divided up on separate sheets so that the layout may be easily seen. Figure 9 shows the evaporators, distilling condensers, water seals, heaters and pumps. To see a certain system of piping, lay out figure 9, then lay out and superpose the figure showing the piping system in question.

Necessary equipment for various size double-effect distilling plants.

Items.	Number of units.		
	Plant A.	Plant B.	Plant C.
Evaporators	8	6	4
Distilling condensers	4	4	2
Feed-water heaters:			
Vapor	2	2	2
Coil drain [1]	4	3	1
Separator, vapor:			
First effect	1	1	1
Second effect	1	1	1
Low-pressure single effect	1	1	1
Measuring tank or meter	1	1	1
Pumps:			
Evaporator feed	2	2	2
Evaporator brine	1	1	1
Distilling condenser circulating	2	2	2
Distilling condenser air	2	1	1
Fresh water	2	2	2

[1] Fitted in first effect evaporator steam coil drains only.

Required size for vapor separator.

Vapor separators.	Vapor separators will be of sufficient capacity to pass the combined vapor from—		
	Plant A.	Plant B.	Plant C.
First effect	4 evaporators	3 evaporators	2 evaporators.
Second effect	do	do	Do.
Low-pressure single effect	do	4 evaporators	Do.

43. **Typical Evaporator Performance.**—Tables I and II below illustrate typical performance of single and double effect evaporators operating with an orifice in the steam line to control the coil pressure for steady capacities of 30, 60, 90, 120, and 150 gallons per square foot of submerged heating surface for 24 hours. The steam-line pressure is steady

at 250 pounds, gauge. The orifices will maintain their particular capacities up to the point when the coil pressure reaches the critical pressure for orifice operation (140 pounds gauge with 250 pounds initial pressure), that is, where the steam flow to coils ceases to be a constant quantity. The shell pressure on the second-effect evaporator, operating double effect, and the shell pressure on the single-effect evaporator were 1 pound gauge. The total running time for both Tables I and II is the time up to the point when the orifice ceases to maintain constant capacity and when it is necessary to remove the scale from the coils. These tables are based on the vertical coiled tube type of evaporator but the variable quantities will vary in a similar manner with any type.

The fact that the coil pressure on this typical test was allowed to run up to 140 pounds gauge must not be taken as in any way authorizing or recommending the use of a pressure in the first-effect coils above that of the designed relief valve setting. In actual operation, the total running time, without cracking or removing scale, would be much shorter than that given in the typical examples. The typical examples use coil pressures up to 140 pounds gauge simply to illustrate conditions up to the time when the orifice ceases to function.

TABLE I.—*Performance of single-effect evaporator equipped with orifice, steam pressure in line 250-pound gauge, shell pressure second effect 1-pound gauge.*

(Continuous blow, salinity 3/32ds.)

	Item.	Source.					
1	Capacity, vapor per day per square foot of surface.	Gallons...........	30	60	90	120	150
2	Coil pressure at start with K=1,000.	Pounds per square inch gauge.	3.50	8.00	13.30	19.50	27.30
3	Coil pressure at end.....	Pounds per square inch gauge.	140.00	140.00	140.00	140.00	140.00
4	Heat transfer coefficient, K, at end.	B. t. u. per hr., per degree T. D. per square foot surface.	70.00	140.00	215.00	285.00	355.00
5	Temperature difference at start with K=1,000.	Degrees Fahrenheit.	9.00	20.00	33.30	46.00	57.20
6	Temperature difference at end.	.....do.............	146.00	146.00	146.00	146.00	146.00
7	Increase in temperature difference.	.....do.............	137.00	126.00	112.70	100.00	88.80
8	Rate of increase in temperature difference.	Degrees Fahrenheit per hour.	0.25	0.50	0.75	1.00	1.25
9	Total running time.....	Hours.............	548	252	150	100	71

TABLE II.—*Performance of double-effect evaporator equipped with orifice; steam pressure in line 250-pound gauge, shell pressure second effect 1-pound gauge.*

(Scale not cracked. Continuous blow, salinity 3/32ds.)

	Item.	Source.					
1	Capacity vapor per day per square foot surface.	Gallons	30	60	90	120	150
2	Coil pressure at start, first effect with K=1,000.	Pounds per square inch gauge.	8.50	19.60	34.70	52.70	74.30
3	Coil pressure at end, first effect.	....do	140.00	140.00	140.00	140.00	140.00
4	Coil pressure second effect at start K=1,000.	....do	4.30	8.30	13.30	18.50	24.50
5	Coil pressure at end, second effect.	....do	38.50	38.50	38.50	38.50	38.50
6	Heat transfer coefficient, both effects at end.	B. t. u. per hr., per degree T. D. per square foot surface.	140.00	140.00	140.00	140.00	140.00
7	Average temperature difference between first and second effect at start K=1,000.	Degrees Fahrenheit.	11.00	21.30	32.30	42.70	52.20
8	Average temperature difference between first and second effect at finish.	....do	73.00	73.00	73.00	73.00	73.00
9	Increase in temperature difference, both effects.	....do	62.00	51.70	40.70	30.30	20.80
10	Rate of increase in temperature difference.	Degrees Fahrenheit per hour.	0.25	0.50	0.75	1.00	1.25
11	Total running time	Hours	248	103	54	30	17

44. Figure 10, insert, shows graphically the typical operation of evaporators in double effect using an orifice in the live-steam supply line to first-effect coils, initial steam 250 pounds, coil steam sufficient to maintain average of about 60 gallons output of fresh water per 24 hours per square foot of submerged heating surface; second-effect shell pressure steady at 1 pound, gauge and scale not cracked or removed from coil, but coils clean at start. In actual operation it would be necessary to shut down and pull coils for scaling, when the first-effect coil pressure reached the designed setting of the coil relief valve. For a relief-valve setting of 80 pounds gauge, therefore, the total running time before scaling would be 80 hours, or 3 days and 8 hours. However, when instructions for cracking scale (6*a*) are carried out, this running time before pulling coils will be materially increased.

REFERENCE READING ON MARINE EVAPORATORS.

Salt water evaporators, calculation of blow-down loss, heat balance, etc. W. L. DeBaufre, Journal A. S. N. E., November, 1915, page 946.

Electric chlorine indicator. Lieut. Commander P. V. H. Weems, United States Navy, United States Naval Institute Proceedings, May, 1919, page 775.

An improved method of operating evaporators. M. C. Stuart, Journal A. S. N. E., February, 1919, page 63.

Test of regenerative evaporating apparatus. M. C. Stuart, Journal A. S. N. E., February, 1918, page 41.

Test of Schutte & Koerting Evaporator. M. C. Stuart, Journal A. S. N. E., November, 1917.

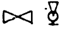
Test of Reilly multicoil evaporator. H. T. Dyer, commander, United States Navy, Journal A. S. N. E., February, 1918, page 78.

Navy standard boiler water-testing outfit and instructions for use. Journal A. S. N. E., August, 1912.

Evaporating plants. H. C. Dinger, Journal A. S. N. E., 1914, page 843.

Article on Lillie plant. Journal A. S. N. E., February, 1913.

PIPE SYMBOLS	DESCRIPTION
————	Live steam to evaporator coils
▬ ▬ ▬ ▬	Auxiliary exhaust to evaporator coils
— — — —	Vapor
→→→→	Fresh water from distilling condensers
—·—·—·—	Circulating water to & from distilling condsrs
- - - - - - - - - - -	Evaporator feed pump suction & discharge
——·——·——	Evaporator steam coil drains H.P.
——··——··——	Evaporator steam coil drains L.P.
•···•···•···•	Vapor separator drains
——·——·——·——	Fresh water pump suction & discharge
•—•—•—•—•	H.P. evaporator blow
—•—•—•—•—	L.P. evaporator blow

SYMBOLS	DESCRIPTION
	Stop valve
	Stop check valve
	Reducing valve
C.D.F.H.	Coil Drain Feed Heater
	Relief valve
	Orifice Valve
W.S.	Water Seal
	Three way cock

Symbols used in Fig 11.

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APPENDIX A.

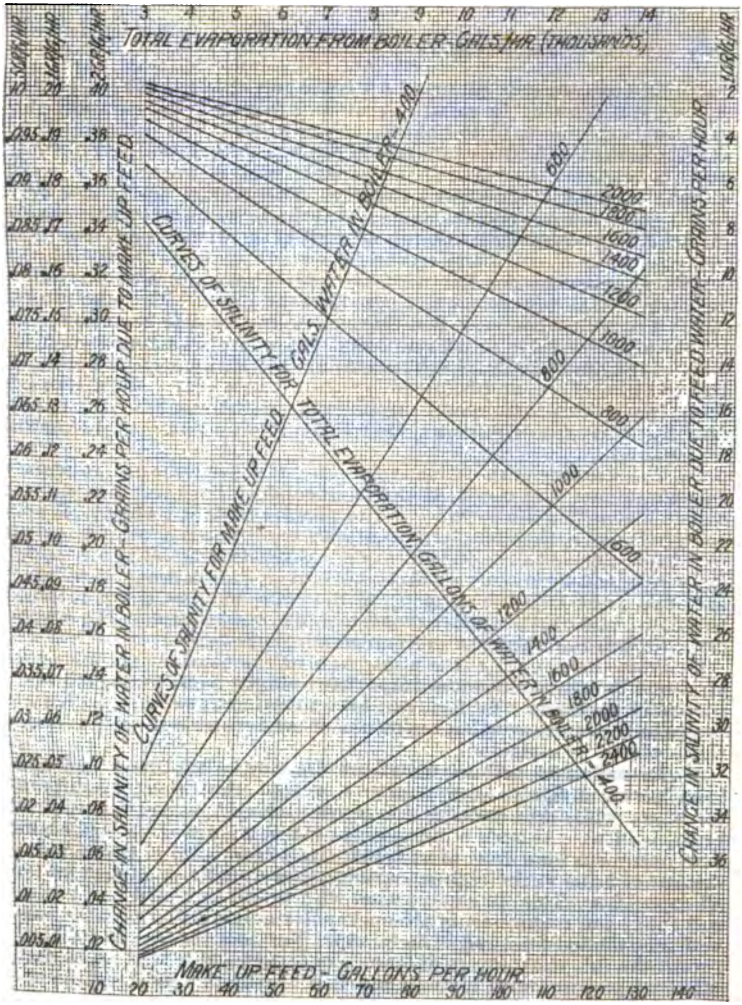

FIG. 12.

APPENDIX B.

(The following is taken from Force Engineering Circular No. 17-20 of the Destroyer Force, United States Atlantic Fleet.)

(*a*) **The evaporator plant of a destroyer,** although of large capacity, must necessarily be small in size, and this very fact provides the most common source of trouble for the operator. The comparatively **small amount of brine** contained in the **small shell** will, when fresh water is extracted therefrom at the designed rate, be the means of causing **the density to rise very rapidly.** The average design of a vertical high-pressure evaporator is such that the brine **density will reach three thirty-seconds in about 40 minutes** of operation, the feed being sea water at one thirty-second density.

Officers and men familiar with the large shells installed on major vessels are prone to overlook this very important fact. They also generally fail to realize the basic fact that, when feeding with sea water, the weight of **brine that must be blown out** of any evaporator shell in order to maintain the brine at three thirty-seconds density, is **one-half the weight of vapor produced by the evaporator.** With a small shell, from which large quantities of vapor are being extracted, it follows that, in a destroyer plant, the weight of brine that must be blown is enormous.

(*b*) **The density** of the brine in an evaporator shell **should be maintained at two and one-half thirty-seconds.** For every one thirty-second above this the capacity of the plant is **reduced about 12 per cent.** There is, therefore, practically no gain in economy by avoiding blowing out brine in the endeavor to save heat **as long as the density does not fall below two thirty-seconds.** In addition, high brine densities cause **rapid scaling up** of the coils, increase the **tendency to prime,** and cause **rapid corrosion** of the interior parts of the evaporator through the liberation of hydrochloric acid.

(*c*) From the foregoing it is apparent that the constant maintenance of correct density is the **most important single item** connected with successful operation. In fact, endless trouble, extra work, and failure to produce even reasonable quantities of good water will surely result if the density is neglected.

(*d*) **In order to assure constant density** a combined feed and brine pump, designed so as to supply, as feed, the correct quantity of sea water while withdrawing the correspondingly correct quantity of brine, is ideal. As such a pump is not fitted the next best equipment is a continuous blow line, of sufficient size to take care of the requisite amount of brine at the highest capacity, and capable to adjustment for all capacities. This, in combination with a well-regulated feed pump, will fulfill the requirements although not automatically as is the case with a combined feed and brine pump. Nor does the continuous blow permit the full temperature difference to be utilized for the reason that sufficient pressure must be maintained in the second-effect shell to enable the brine to be blown out.

(*e*) **A continuous blow line** for a destroyer plant should be of one-half inch (inside) diameter. This pipe will more than take care of the density at highest capacity and will do so even if choked with salt to a certain extent. A three-eighth inch or even a quarter-inch line will also take care of the density, but these sizes are more liable to become choked.

The line for each evaporator should be tapped into the evaporator shell over the main bottom blow line, and at a height above that line of **not less than 8 nor more than 12 inches.** If lower than 8 inches the tendency to become choked is increased. If higher than 12 inches the brine of greatest density will not be blown out. The continuous blow line for each effect should be led to the main blow line just beyond the main blow valve.

Under no circumstances should the continuous blow lines from two or more evaporators be led to a common line before being tapped into the main blow line. This will result in the brine from the first effect **backing up into the second-effect shell.**

These should be fitted on the continuous blow line a one-**half inch needle valve.** It is through the medium of this valve that the discharge of brine from the shell is regulated and the density controlled.

(*f*) **A salinometer is absolutely essential;** by no other means can the density be determined. Unless it is determined it can not be regulated.

(*g*) At the bottom of the front of each evaporator there is a gauge glass. **This glass is solely for the purpose of determining whether the coils are being properly drained.** It is in no sense a glass for the determination of water level nor is it intended to show the existence of a water seal. The appearance in this glass of any water whatever indicates imperfect drainage and obviously decreased output.

(*h*) At the top of each water column carrying the gauge glasses referred to there must be **an air cock.** When the plant is in operation these cocks must be opened an amount sufficient to **free the coils from air,** and show an occasional puff of white steam. The difference between air and steam can be readily determined by observation and by passing the bare hand through the escaping blast. Air will be comparatively cool.

It is obvious that **air in the coils will reduce the output.**

(*i*) The plant as installed should be **carefully checked** with the drawings to see that no errors have been made by the shipbuilders during the installation.

(*j*) **The drainage should be frictionless.** The coils drain by no force other than gravity. The drains from the coils should lead direct to the hot well and condensers, should not be led to a line carrying other drains, and should be free from sharp bends.

(*k*) Except for the installation of the continuous blow lines and the rectification of the drain lines, any **changes in design** or **alterations** to the plant **are forbidden.** It has been amply demonstrated that none, other than those specified, are necessary.

5. With the above essentials in mind the **operation of the Reilly plant in double effect** should be as follows:

(*a*) **Start distiller circulating pump** and evaporator feed pump and fill the shells to about 10 inches in the glass. When evaporators are in full operation the brine level inside the evaporators is from 6 to 12 inches higher than the level indicated in the glass. This is due to foaming.

(*b*) With steam valve to first-effect evaporator coils closed, open all other steam, vapor, or drain valves that are intended to be open when plant is in full operation. The vapor valve between the first shell and second effect coil should be **wide open.**

(*c*) **Open air cocks** on coil drains and on coil drain traps or water seals.

(*d*) **Gradually open steam valve** to first effect coil, carrying no more than 35 to 40 pounds, until the plant is thoroughly warmed up and operating at about one-half capacity.

(*e*) **Adjust water seal** on high-pressure drain collector. None is required on second-effect coil drain line, which is led direct to distillers.

(*f*) **Adjust vapor valve** from second-effect shell to carry not less than 5 pounds vapor pressure (gauge) nor more than 10 pounds (gauge). With less than 5 pounds the continuous blow from the second-effect shell will not surely function on account of the necessity for overcoming the pressure of the sea outside. The higher the vapor pressure in the second-effect shell the less will be the tendency to prime.

(*g*) **Gradually open steam valve** to first effect evaporator coil until 70 pounds is reached unless the coils have been newly scaled by hand, in which case **not more than 40 pounds** can be carried until the plant has been in operation for at least 12 hours. The scale that forms on the coils during this time will gradually check violent ebullition and permit the full working pressure to be carried.

(*h*) **Adjust the continuous blow valves** empirically and continue to take the saturation with the salinometer until the proper setting of these valves has been determined. Thereafter the saturation should be taken each time two tanks of water have been made.

(*i*) **Adjust the amount of distiller circulating water** to suit the actual needs of the amount of vapor to be condensed. If the feed is being taken from the distiller circulating discharge, the discharge should be as warm as the feed pump can handle without the distillers at the same time becoming overheated. If, for any reason, it is desired that the distillate be cold, considerably more circulating water will be required than will be the case if the discharge water is used for feed.

(*j*) **Note the time** that is taken for the measuring tank to fill with distilled water. Continue to note and record the times necessary to fill successive tanks. If these times increase steadily during a period of, say, 4 hours (other conditions remaining the same), the density is increasing, and this can be verified by increasing the amount of blow and noting the decrease in "elapsed time to fill one tank."

(*k*) **As the coils become coated with scale** the pressure in the high-pressure coils will have to be increased. Otherwise the output will decrease. If, however, the scale is cracked twice daily from the coils, no abnormal increases in pressure should be required. The method of cracking scale is described later.

(*l*) In the Reilly evaporator **maintain the high-pressure water level at 15 inches** above the bottom nut on the gauge glasses; the low pressure slightly lower than this. If the ship is rolling, the water level must be lowered somewhat. In the bureau type of destroyer evaporator the water level should not exceed 6 inches in height.

6. With the plant in operation under stable conditions as described above the **rated capacity of pure water should be continuously** produced for periods of at least 12 hours. During this time of operation the operator should test each tank of distilled water and distribute it to the ship's tanks or for feed as directed. He should constantly observe the steam pressures and the water levels, regulate the speed of the pumps as necessary, note the times taken to fill each tank, take the density by salinometer after every second tank, and regulate the continuous blow valves accordingly, giving extra blows with the main valves as necessary.

7. At the end of 12 hours of operation **scale should be cracked** from the coils by the following method:

(*a*) **Completely blow down the evaporators** and shut off steam. This is accomplished by closing vapor valves so as to build up about 25 pounds pressure in the shells, and then opening the main blow valves wide.

(*b*) **Allow the shells to fill** to the top of the coils with cold feed from the sea through the main bottom blows.

(*c*) **Suddenly turn on steam to the coils** up to at least 60 pounds pressure (gauge) and maintain this pressure until coils are thoroughly heated. The sudden change of temperature will cause sudden expansion of the coils, and this will crack off the scale. Pressure should then be allowed to build up to 25 pounds in the shells, after which the shells should be again blown completely down. The scale which has cracked from the coils will accumulate in the bottom of the shells, and a considerable part of this will blow out through the main blows, if these are large.

This, however, **will not remove all the loose scale** and sludge from the bottoms of the shells, and it will be necessary to remove this from time to time by means of the handholes or by drawing the coils. When the coils are drawn, which should be once a month (but not oftener if scale is consistently cracked as described above), they should be tested for leaks to 150 pounds, and such scale as has not cracked off should then be removed by hand. At the same time the interiors of the shells should be thoroughly cleaned.

8. **If trouble is experienced in producing large quantities of pure water,** knowledge of the following will assist the operator to locate the cause.

9. **Priming.**—Priming is the carrying over, with the vapor, of small particles of the brine. It is caused by agitation of the surface of the brine. It is detected by the presence of excess chlorine in the distillate, and, when excessive, by fluctuation of the water in the gauge glasses. The following will cause priming:

(*a*) **Too high density.**—This is verified by the salinometer. The fact that the elapsed times to fill successive tanks with distilled water are steadily increasing indicates increasing density. The remedy is larger opening of the continuous blow valves, and additional blows with the main blow valves if necessary. Water level too low will cause the density to rise rapidly.

(*b*) **Too low vapor pressures.**—If priming occurs when the second-effect vapor pressure is not less than 5 pounds (gauge) increase the vapor pressure up to 10 pounds by closing down the vapor valves, and then gradually open it until 5 pounds is again reached. If priming continues, reduce the first-effect coil pressure, maintaining the second-effect pressure steady at 5 pounds. The temperature difference between the first-effect coil and the first-effect shell may be too great and this will cause the first effect to prime. Reducing the first-effect coil pressure will reduce the temperature difference, which should not exceed 50° F. (see tables of Properties of saturated steam). As noted previously, with the coils very clean, the coil pressure must be very considerably reduced in order to prevent priming.

(*c*) **Nonuniformity of operation.**—With continuous blow valves correctly set and water levels maintained at a constant height, the plant should remain in a stable condition. Failure of the reducing valve will upset the equilibrium of the plant.

(*d*) **Too high brine levels.**—While on an even keel these, as previously stated, should, in the Reilly evaporators, be at 15 inches above the bottom nut on the high-pressure water column; somewhat lower in the low pressure. Lowering the water level below these heights in an endeavor to prevent priming will cause the density to increase at a more rapid rate and may cause priming because of nonuniformity of operation. In the Bureau type of destroyer evaporator the water level must not be higher than 6 inches.

(*e*) **Sudden fluctuations of brine levels.**—These may be caused by the improper functioning of the feed pump, or by sudden opening of the main blow, or the rolling of the ship.

(*f*) **Sudden opening of vapor valve.**—This will invariably produce priming.

(*g*) **Fluctuating drainage of the evaporator coils.**—This is caused by a trap that is not operating steadily and is detected by observing the operation of the trap.

10. **The following will decrease the output:**

(*a*) **Too high density.**—This has been dwelt upon at length above. The density should be known to be correct before the cause of decreased output is searched for elsewhere. The operators should be carefully instructed in the use of the salinometer in order that reliance may be placed on the readings reported.

(*b*) **Coils airbound.**—See the air cocks open sufficiently wide to release an occasional puff of steam.

(*c*) **Imperfect drainage.**—If the installation has been found to be correct, and the drain water from the coils is not led to a line that also carries other drains, the trouble is in the traps or drain collectors which may be airbound. Water showing in the gauge glass at the bottom of the front of the evaporators indicates imperfect drainage.

(*d*) **Coils need scaling.**—If this is the trouble it will be indicated by excessive coil pressures being required. In attributing the trouble to this cause, the time that has elapsed since the coils were drawn as well as the thoroughness with which they were then scaled should be taken into account. Perhaps the operators have not been cracking scale properly and at regular intervals.

(*e*) **Live-steam valve to second-effect coils leaking.**—While the plant is being operated in double effect the vapor from the first-effect shell is led to the second-effect coils and the live-steam connection to the second-effect coils should, of course, be known to be tightly closed. Should this valve leak, or be partially open, live steam will enter the second-effect coils and back up into the first-effect shell. This will partially nullify the work of the second-effect evaporator and thus decrease the output. The repeated lifting of the relief valve on the first-effect shell while attempting to carry normal pressure in the first-effect coils is an indication of this condition.

(*f*) **First-effect vapor passing direct to distillers.**—While operating in double effect the valve on the line from the first-effect shell to the distillers should, of course, be known to be tightly closed. Should this valve leak or be partially open the second-effect coils will be robbed of their steam and reduced output will result. The condition is the equivalent (approximately) of single-effect operation with only the first-effect evaporator in use.

11. **The following will cause the chlorine content of the distillate to be greater than that permissible:**

(*a*) **Priming.** (See causes of priming above.)
(*b*) **Feed heater leaking.**
(*c*) **Leaky coil.**

In order to locate the cause of excessive chlorine content, first be assured that priming does not occur. Then cut out the feed heaters. If the distillate shows excessive chlorine, cut out first one distiller and then another.

A leaky coil will not only cause agitation of the surface of the brine and thus produce priming, but will also **cause the distillate to become contaminated** by impurities from the boiler steam, and can usually be detected by tasting the distillate. If the distillate is contaminated by boiler steam it will probably show an **alkaline reaction.** If a leaky coil is suspected, blow down the evaporator and, with steam on the coil, note whether or not pressure rises in the empty shell. **This test should always be applied** when scale is cracked. A leaky coil should be remedied at once. The coil itself may not actually be ruptured. The leak may be in one or more of the joints where the coil connects to the manifold.

12. **If a ruptured coil or leaky joint is present** there is danger of salting up the entire system when blowing down. The brine may be blown through into the interior of the coil and finds its way, via the drain line, to the feed tank or condenser and thence to the boilers. The drain lines should be closed off when blowing down and cracking scale and, when the blowdown is completed, the coils should be drained through a pet cock and the water from the drain line should be tested for chlorine.

13. **If there is an increase in the amount of "make-up feed" required,** no usual leaks in the steam or fresh-water lines being located, it is quite possible that the coil steam is passing through a leak in a coil and into the brine. Thus boiler steam is being mixed with the brine and lost.

14. In this same connection mention should be made of **a puzzling situation** which frequently has been encountered. A very marked increase in the demand for ' make-up feed" is noted while the evaporators are apparently producing full capacity of distilled water. No leaks in any of the fresh-water lines can be found, and the boiler bottom and surface blows and safety valves are known to be tight.

This situation is caused by **boiler steam passing direct to the distiller** while operating in double effect. As the plant is piped both for single and double effect operation there is necessarily a connection from the first-effect shell to the distillers. There is a connection for live steam to the second-effect coils and this is a continuation of the live-steam line to the first-effect coils. When operating in double effect, the first-effect vapor, instead of passing through to the distillers is led to the second-effect coils and a valve is closed to prevent live steam from going to the second-effect coils. At the same time another valve prevents the first-effect vapor from going direct to the distillers.

If, now, the valve on the live-steam connection to the second-effect coils is not closed tight, or is leaking, while at the same time the direct connection from the first-effect shell to the distiller is partially open because of a leaking or partially closed valve, **live steam will pass direct to the distillers** and be condensed there.

This will cause the evaporators apparently to produce large quantities of water (part of which is condensed boiler steam) while the boiler steam that is being condensed in the distillers is not only a direct loss of heat but calls for additional "make-up." The result is that the evaporators are kept going in an endeavor to supply sufficient "make-up." An extra demand for "make-up" is being created through this very fact, normal demands for fresh water continue, and the reserve supply of feed and drinking water goes steadily down until the condition becomes really serious.

When the engineer is confronted with such a situation, **the plant should be shut down** and demand for "make-up" noted. If the apparent extra demand for "make-up" ceases when the plant is not in operation, the trouble is surely in the valves referred to. They should be immediately overhauled and known to seat tightly.

In the above case, the **taste of the distillate** will probably be such as to lead the engineer to suspect that boiler steam is passing direct to the distillers. If the distillate also shows an alkaline reaction the suspicion may be considered confirmed.

Still another condition may arise and confuse the engineer. In this case there appears to be a **gain in capacity while the demands for "make-up" increase.** It becomes necessary to run longer than usual on the reserve tanks in order to compensate for the additional "make-up" that is being (apparently) used. At the same time the ship's tanks are being filled at an unusual rate. Again no leaks can be found in any of the fresh-water or steam lines.

The trouble is that the **first-effect coil drain water** (condensed boiler steam that ordinarily is returned to the feed tank) **is being sent to the distillers.** The drain water from the second-effect coil (being really distilled water) should go to the distillers while the drain water from the first-effect coil should go to the feed tank or condenser. There is a valve to prevent the drain water from the first-effect coil entering the pipe carrying the drain water from the second-effect coil.

If this valve is open or is leaking the drain water from the first effect coil will go to the distillers with the drain water from the second effect coil. This causes an apparent increase in the quantity of distillate. At the same time the feed tank has been deprived of this amount of water and there is an apparent increase in the amount of "make-up" required. There is really no loss anywhere although the distillate is being contaminated by impurities in the condensed boiler steam. The taste of the distillate should indicate this and the valve in question should be made tight.

15. **Single effect operation should never be resorted to** unless one of the evaporator units is not in operating condition, or unless the plant is being operated with exhaust steam in the coils. To operate in single effect is to throw away about 45 per cent of the fuel used to produce a given quantity of water. The plants installed on all 1,200 ton destroyers will, when operated in double effect, produce pure water at the rate of at least 125 per cent of the rated capacity. This has been amply demonstrated.

EXHAUST STEAM OPERATION.

16. **With exhaust steam of not more than 12 pounds pressure** (guage) in the coils, and with sea water as feed, the plants in single effect will produce at least 30 per cent of the rated capacity. This quantity of water is ample for the normal needs of a destroyer in port. Operation with live steam should not, therefore, be necessary except when the element of time has to be considered, or while at sea, or when operators are not available for continuous watch.

17. While operating with exhaust steam in the coils the **continuous blow lines can not be used** because the pressure in the shells is necessarily too low to blow the brine overboard. The density must, therefore, be controlled by giving partial blows through the main blow valves. These should be given when the density rises to two and one-half thirty-seconds and, in amount, should be whatever is required to reduce the density not below two thirty-seconds. As a guide it should be noted that, in order to maintain the density at two and one-half thirty-seconds, about 9 inches should be blown from the gauge glass of each unit of the 7,500 gallon plant and about 7 inches from the gauge glass of each unit of the 10,000 gallon plant for each 100 gallons of distillate produced.

18. Operation under exhaust steam requires exactly the same valves to be opened as does single effect operation under live steam, except that the live steam valve to the reducing valve must be closed **tightly** and the exhaust connection opened. In starting the plant the same procedure as heretofore given is used, except that the exhaust steam has to be turned on **gradually**, as the **auxiliary exhaust will drop very suddenly** if opened quickly to cold coils.

The inherent feature in the destroyer design evaporator plant of having **a small capacity for brine** is partially overcome by correct exhaust steam operation since water levels from 4 to 6 inches from the top nut of the gauge glasses **may be carried without danger of priming**. As a result of this increased brine capacity during operation, the **coils stay clean much longer** and scaling by hand does not have to be resorted to more often than once every two months. It has been found advisable to self scale the Reilly type evaporator once a day with live steam while under exhaust operation. This may be done more often, but it is not believed the time lost to blow down more often than once a day is commensurate with the increased capacity of the plant due to blowing down, since a very thin coat of scale on the coils is much harder to dislodge by the expansion and contraction of the coils than is a thicker coat.

19. Since the initial pressure of the steam to the coils is only 12 pounds gauge it is essential, in order to get a reasonable capacity from the plant, to pay particular attention to the (1) **shell pressures,** and (2) **temperature of the feed.**

For (1) all vapor valves should be wide open after the plant warms up to get the maximum temperature difference between the shell pressure and coil pressure. For (2) the amount of water to the distillers should be regulated so that the operator can just bear his hand on the discharge from the distillers. Cutting down too much on the distiller circulation will result in vapor blowing through the distillers, and in fluctuating shell pressure, thus subjecting the distillers to extreme temperature differences, eventually causing them to leak. Worst of all a formation of scale will be formed on the distiller tubes; this decreases the distiller capacity and the entire capacity of the plant when maximum output is desired under conditions where the injection is warm. Also this scale decreases the distiller efficiency since heat transfer is decreased and more cooling water is required to distill the same amount of vapor and therefore the efficiency of the entire engineering plant is decreased. Scale on distiller tubes is extremely difficult to remove.

20. For exhaust operation slightly lower densities may be carried than with double effect operation. The density should be two to two and one-half thirty-seconds. While decreased densities may seem at first to defeat the first essential of exhaust operation by wasting some of the heat, the fact remains that the loss of capacity due to the accumulation of scale must not be overlooked and that the first requisites of a good capacity on exhaust operation are clean coils and a method of operation whereby coils are kept comparatively clean. Also it will usually be found that in port more exhaust is on hand than can be used in the evaporators and feed heaters and since this is the case it will be no loss in fuel whatsoever to blow down more often. In fact, an actual gain in the long-run operation of the plant in capacity, upkeep, and time out for overhaul will result.

While evaporators are making water for "make-up" feed, it is desirable to run the drains from both coils through the drain feed water heater to the distillers, thus obtaining increased feed water temperature. This, however, can not be used when making water for drinking purposes, since approximately one-half the water in each tank is condensed boiler steam. When feed is being made with the drains to distillers each tank should be counted as 25 gallons instead of 50 gallons actually made. This figure will vary slightly for different installations. For destroyers not already equipped with a separate drain from the evaporator coils to the hot well and condensers, this method presents a partial solution for independent drainage while making feed water.

21. Since operation under exhaust steam is much slower than with live steam, the distillate contains less chlorine than is possible with live steam. This feature is one of the strongest arguments for exhaust operation, since it is a great saving of water and labor. Under good operation boilers need never be blown down and it is possible to run continuously for periods as long as four months without the chlorine content in the boilers in use exceeding 5 grains and without having to change the water in boilers. Boilers at the end of a long period of operation as above will show no corrosion, practically no scale in the tubes or drums, and will be very easy to clean.

Actual experience for a period of over nine months on an operating destroyer, where the exhaust operation has been gone into thoroughly, has demonstrated that it is easily possible to make enough water on exhaust to meet all needs, and that with good operation live steam need never be used to make water. The accomplishment of this necessitates more than ever a tight engineering plant and daily inspections for leaks on the part of the engineer officer.

22. Although not directly connected with evaporator operation on auxiliary exhaust, the following method of checking up to see that no salt gets into the boiler has a vital bearing on the success of making enough water to continually meet all needs, in that it practically makes it impossible to get any salt into the boiler in port, thus eliminating the usually large item of dumping and blowing down boilers.

Every tank should be tested just before pumping by the evaporator operator and all water intended for feed should be put into the hot well.

Suction with the auxiliary feed pump should be taken on C-101 or any feed tank, except the hot well. It has been found that in port with the large capacity feed heaters as installed on the present destroyers there is no appreciable difference in the temperature of the feed at the boiler when suction is on a feed tank or on the hot well.

The man on auxiliary watch then, as a check on the evaporator operator and the entire plant, makes a separate test and entry in the log as soon as the hot well is full and if the test is satisfactory runs the hot well quickly down to the level of the running back line to the reserve feed tank, which is about 300 gallons. Thus a double check is obtained on all water distilled, a single check on all other water entering the hot well, and the large reserve feed tanks and boiler absolutely protected from salt.

From actual experience leaky evaporator coils have brought the hot well up to 40 grains without salting up either the boiler or reserve feed tanks and the only water lost has been the water in the hot well and that required to wash it out. There will never be any excuse for salting up in port if the above method is carried out conscientiously.

23. An additional pump for the purpose of carrying a vacuum on the distillers will be experimentally installed on several destroyers. With such a pump a vacuum of 14 to 16 inches should be carried and, with 12 pounds of steam in the coils, a capacity of 50 to 60 per cent rated capacity is easily attainable while feeding with sea water. This should render operation with live steam unnecessary except on rare occasions or in emergency.

24. The exhaust from turbogenerators must not be sent to the evaporator coils.

25. The great saving in fuel that will result from operation with exhaust steam is a matter of vital importance and the necessity for the employment, to the limit, of exhaust steam should be impressed upon the minds of all those having to do with the administration of naval vessels.

TEST OF DISTILLATE.

26. Each tank of distillate should be tested, using the standard Navy testing outfit according to instructions furnished therewith, except that it is preferable to use 10 drops of chromate indicator instead of 5. This is merely to render more readily discernible the point at which the reaction takes place.

Distillate containing more than 0.5 grain of chlorine per gallon should not be sent to the reserve tanks for use in the boilers of a destroyer.

Water containing as high as 4 grains of chlorine is harmless for drinking and cooking and is tasteless.

27. The following will assist in clearing up a confusing condition which is sometimes encountered while testing water for chlorine:

A specimen of water, known to contain 0.4 grain of chlorine per gallon, and further known to be slightly acid, was tested for chlorine.

Ten drops of potassium chromate were added and a decided yellow color resulted.

Silver nitrate solution, in quantity far in excess of that required to indicate 0.4 grain of chlorine, was then added and failed to bring about any reaction. **The further addition of one drop of potassium chromate gave a blood red color at once.**

If, in testing water, a sample believed to contain but a small amount of chlorine should fail to show a reaction after a considerable excess quantity of silver nitrate solution has been added, **acidity is to be suspected.** Take another specimen of the water, add methyl orange indicator, and look for the rose color denoting acidity.

If acidity shows, the specimen may be neutralized with the sodium carbonate solution furnished with standard outfit, and then tested for chlorine in the usual manner.

STANDARD RULES FOR PERIODICAL TESTS OF DESTROYER EVAPORATING PLANTS.

The test for capacity and purity of product of each plant will be conducted under the following rules:

1. Squadron commanders appoint umpires and assistants and designate dates for holding the tests within the period prescribed by the force commander. Inform force commander of dates designated.

2. There shall be present during the test **one umpire,** who shall be the executive officer of a destroyer other than the one under test, and **three assistants** who shall be enlisted men from a destroyer other than the one under test. The duties of the umpire shall be to observe the tests, to supervise and check the collection of data, and to require adherence to these rules. The umpire has no authority over any part of the personnel or material of the destroyer under test, but is the final judge of facts.

3. **The duration of the test** shall be 4 hours. Once begun the test shall be carried through to completion, and no allowance shall be made for interruption within the ship or for derangement or casualty.

4. **The evaporator plant shall be put in operation** at such time, not to exceed one hour, prior to the test as the umpire may request. The test shall be begun whenever the commanding officer of the destroyer under the test shall select, but, if the test is not begun within one hour after the umpire requests that the plant be put into operation, the test shall be declared to be begun one hour after the umpire so requests and shall terminate exactly four hours thereafter.

5. **The measurement of the quantity of the distilled product** shall be made and recorded in the presence of the umpire, who shall check the capacity of the measurement tanks prior to the test. Each tank of distilled water shall be tested and the chlorine content determined by the umpire personally or by one of the assistants in the presence of the

umpire. Samples used for the test shall be taken just before the tank is pumped out. More than one sample from each tank may be tested if the umpire so elects and, if this is done, the official chlorine content of that tank shall be the average of the chlorine content of the several samples.

6. The standard method of determining chlorine content as given in the pamphlet Description of the Navy Standard Boiler Water Testing Outfit and Instructions for Use shall be adhered to and the apparatus therein described only shall be used. Ten drops of chromate indicator shall, however, be used instead of four. The testing outfit shall be set up and used on deck.

7. Unless otherwise specified the plant shall be operated in double effect throughout the test by one or more of the officers or (and) men regularly attached to the destroyer under test. The density of the brine in each shell must be taken after every second tank of water distilled and commanding officers will take necessary steps to see that salinometers are provided for this purpose.

When it is directed that the plant be operated with exhaust steam only, the following modifications shall apply.

(*a*) The plant shall be operated in single effect with exhaust steam at not more than 12 pounds pressure (gauge).

(*b*) The machinery in operation shall be confined to the following:

1 fireroom blower.
1 fire and bilge pump (flushing).
1 boiler feed pump.
1 fuel oil service pump.
1 auxiliary air and circulating pump.
Evaporator auxiliaries.

(*c*) The exhaust from the generators shall not be sent to the evaporator coils.

(*d*) The speed of the fireroom blower shall be limited to 450 revolutions per minute.

(*e*) All connections from the coils to the vapor lines and distillers shall be examined by the umpire who shall, in his report, state that such connections were tight (or otherwise) and that there was not (or was) any possibility that steam, other than that produced in the shell of the evaporator, was sent to the distillers and included as distilled water.

(*f*) Live steam connections to the coils shall be securely closed and known to be tight.

8. The final score shall be calculated as follows:

The actual quantity, in gallons, contained in each tank shall be decreased 10 per cent if the chlorine content per gallon of water in that tank is more than 0.5 and less than 0.71 grain. If the chlorine content is between 0.7 and 1.0 grain per gallon the actual quantity shall be reduced by 30 per cent. If the chlorine content be 1 grain per gallon or more, that tank of water shall be rejected in calculating the score. The actual quantity, thus decreased, will be known as the corrected quantity.

The corrected quantity for each tank having thus been determined, the several corrected quantities shall be added and the sum divided by the rated capacity of the plant for four hours. The quotient thus obtained, expressed as a percentage to one decimal place, shall be the final score.

9. For each tank of water distilled there shall be recorded the following data:

(*a*) Elapsed time, in minutes and seconds, to fill the tank.
(*b*) The actual quantity in gallons, contained in that tank.
(*c*) The chlorine content, in grains of chlorine per gallon.
(*d*) The pressure in the first-effect coil.
(*e*) The pressure in the first-effect shell.
(*f*) The pressure in the second-effect coil.
(*g*) The pressure in the second-effect shell.
(*h*) The height of water, in inches above the nut, shown in the first and in the second effect gauge glasses.
(*i*) The amount of opening of the continuous blow valves, for each effect, in fractions of a turn.
(*j*) The amount of water blown from each shell in addition to that blown through the continuous blow valve expressed in inches on the gauge glass.

In addition the following information shall be obtained:

(*k*) The density of the brine in each shell at the end of every second tank of distilled water.
(*l*) Whether or not a water seal in the drain line from the first-effect coil was used and maintained.
(*m*) Same for drain line from second-effect coil.
(*n*) Whether or not the air cocks from the coils were open sufficiently throughout the test to keep the coils free from air.
(*o*) If operating with exhaust steam, statement of machinery in operation.

10. Each umpire shall submit report in quadruplicate, embodying the data required in rule 9 above, and the calculation of the final score (rule 8), infractions of these rules, and such comment, criticism, and recommendation as he may desire to make.

There shall be attached to the umpire's report a statement from the commanding officer of the destroyer under test, giving the following information:

(*a*) The errors of the gages in use, with date of latest calibration. If the gages have not been tested within 60 days they must be tested prior to the tests of the plant.
(*b*) A pencil sketch (not drawn to scale, but with measurements indicated) of the method of connecting up the continuous blow lines. (May be omitted if previously reported.)
(*c*) The date the coils were last scaled by hand.
(*d*) The dates the following were last tested for leaks:
  (*a*) Coils.
  (*b*) Distillers.
  (*c*) Feed heaters.

11. Within twenty-four hours after the completion of the test furnish the original to the commanding officer of the destroyer under test and copies direct, without indorsement, to division, squadron, and force commanders. Printed forms for the umpire's report may be obtained from the force commander.

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